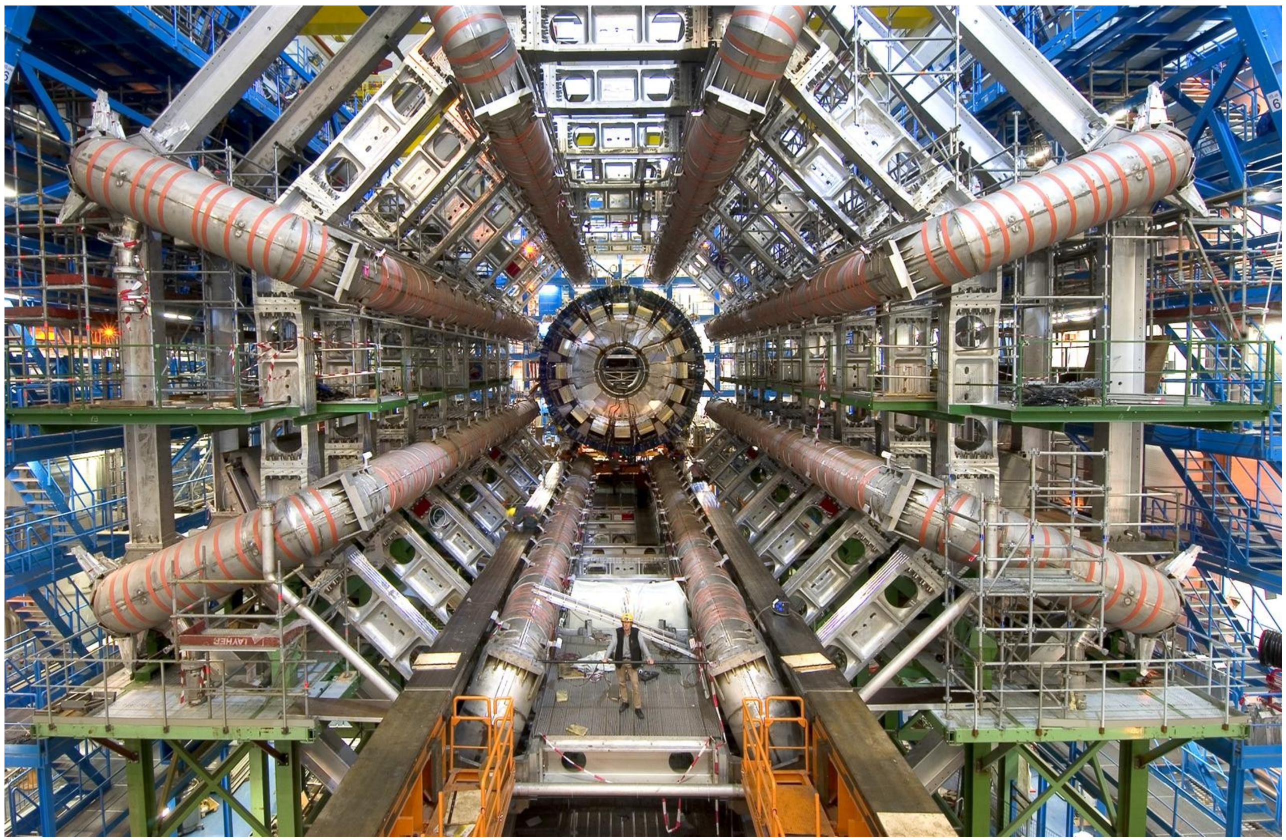
Searches for electroweak production of supersymmetric neutralinos, charginos and sleptons with the ATLAS detector



Tina Potter

On behalf of the ATLAS Collaboration

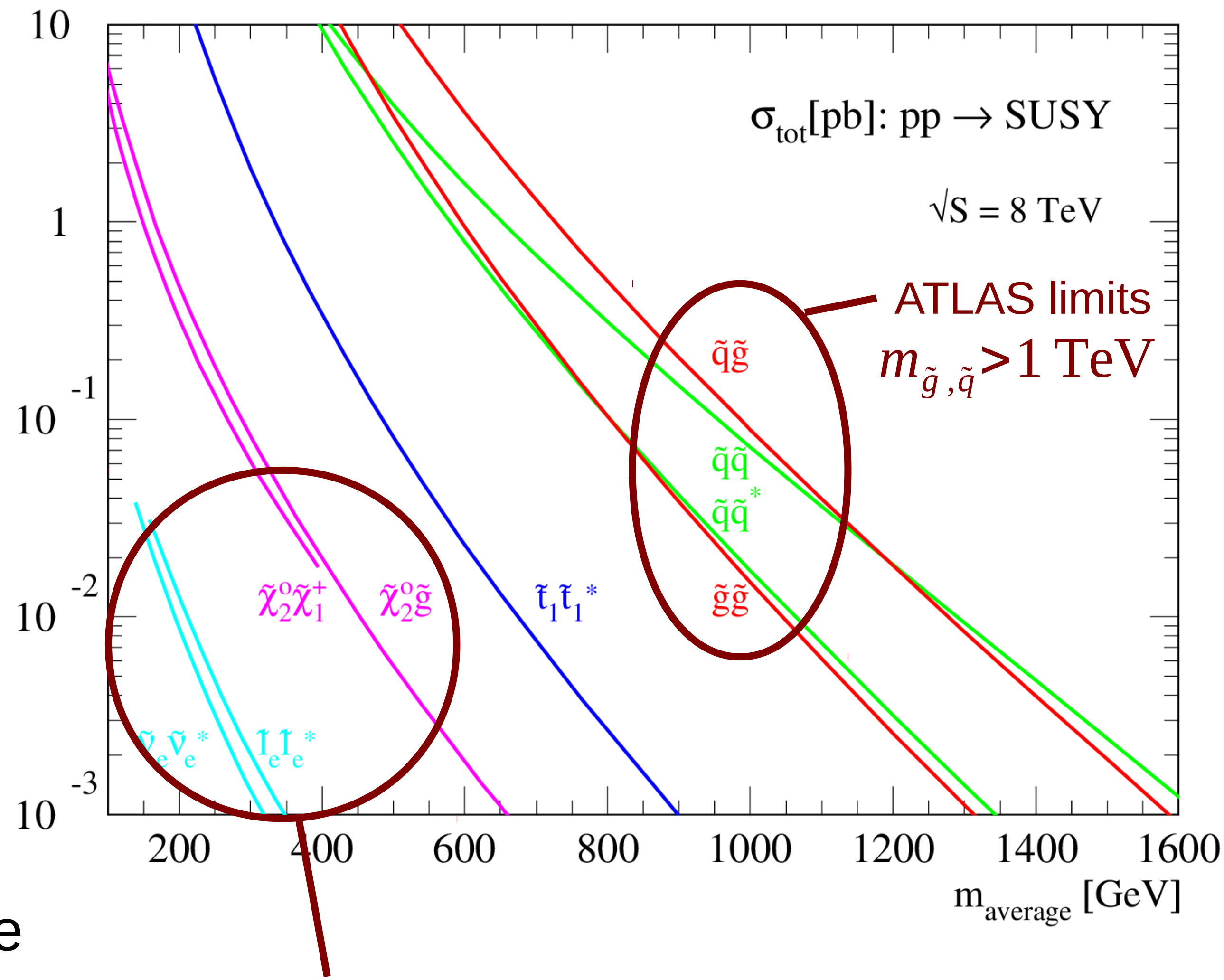
University of Sussex

ATLAS

Charginos and Neutralinos are expected to be among the lightest supersymmetric particles

Natural SUSY
Light stops and gauginos/higgsinos to cancel divergences in higgs mass

Charginos/neutralinos decaying via sleptons/sneutrinos, gauge bosons or higgs can lead to **high lepton multiplicity**



Direct gaugino/higgsino/slepton production may be the dominant SUSY cross-section at the LHC

Search Strategy

$\int Ldt = 20\ fb^{-1}$, $\sqrt{s} = 8$ TeV dataset

- Slepton Pair Production $\tilde{l}^+\tilde{l}^-$ — 2L
- Stau Pair Production $\tilde{\tau}^+\tilde{\tau}^-$ — 2τ
- Chargino Pair Production $\tilde{\chi}_1^+\tilde{\chi}_1^-$ — 2L, 2τ
- Chargino-Neutralino Production $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ — 2τ, 3L, 1L
- Neutralino Pair Production $\tilde{\chi}_2^0\tilde{\chi}_3^0$ — 4L

2 lepton final states (e,μ)
ATLAS-CONF-2013-049

2 hadronic τ final states
ATLAS-CONF-2013-028

3 lepton final states (e,μ)
ATLAS-CONF-2013-035

4 lepton final states (e,μ,τ)
ATLAS-CONF-2013-036

1 e/μ + bb final states
ATLAS-CONF-2013-093

Simplified models studied
Bottom-up approach, capturing essential features of existing models.
Small number of sparticles, assumed BR.
Described by masses and cross-sections.

Long-lived electroweak searches covered by Nimrod Taiblum

Electroweak RPV searches covered by Nick Barlow

Standard Model Background Modelling

SM processes can be SUSY-like – single/di-/tri-bosons, top, multijet, higgs
Need to understand and accurately model the SM backgrounds

Reducible backgrounds
1–2 fake leptons or hadronic taus
Determined from data
Analysis dependent

Irreducible backgrounds
Sources of real, prompt leptons
Dominant sources:
- Control regions in data used for normalisation
- Transfer to signal regions using MC

Sub-dominant sources: MC simulation

Validation Regions
for cross-checks

Signal Regions
Multiple signal regions per channel

Discriminating variables
E_T^{miss}, m_T, m_{ll}, # (b-)jets, $E_T^{miss, rel}$, m_{T2}, m_{CT}

$E_T^{miss, rel}$ projection of E_T^{miss} on perpendicular axis
Reduces mis-measured E_T^{miss}

$$E_{\mathrm{T}}^{\mathrm{miss,rel.}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi_{\ell,j} \geq \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\Delta\phi_{\ell,j} & \text{if } \Delta\phi_{\ell,j} < \pi/2 \end{cases}$$

m_{CT} contransverse mass

$$m_{\mathrm{CT}}^2 = \left(E_{\mathrm{T}}^{b_1} + E_{\mathrm{T}}^{b_2}\right)^2 - \left|\mathbf{p}_{\mathrm{T}}^{b_1} - \mathbf{p}_{\mathrm{T}}^{b_2}\right|^2$$

Kinematic endpoint ~ $m_{\mathrm{CT}}^{\mathrm{max}} \approx \frac{m_{heavy}^2 - m_{invis}^2}{m_{heavy}}$

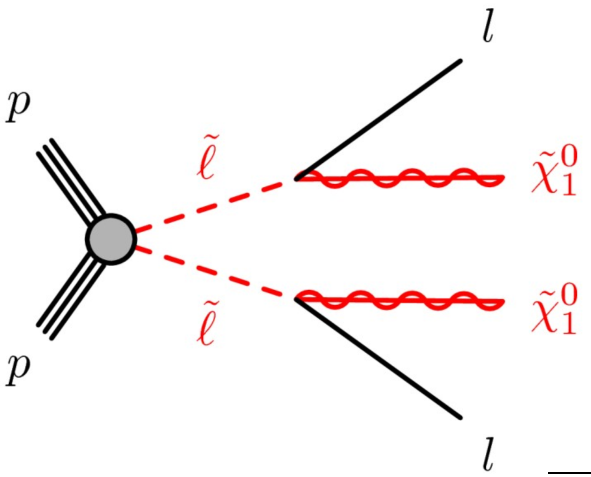
m_{T2} stransverse mass
kinematic endpoint ~ mass of decaying particle

$$m_{\mathrm{T2}} = \min_{\mathbf{q}_{\mathrm{T}}}\left[\max\left(m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}^{\ell 1}, \mathbf{q}_{\mathrm{T}}), m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}^{\ell 2}, \mathbf{p}_{\mathrm{T}}^{\mathrm{miss}} - \mathbf{q}_{\mathrm{T}})\right)\right]$$

where $m_{\mathrm{T}}(\mathbf{p}_{\mathrm{T}}, \mathbf{q}_{\mathrm{T}}) = \sqrt{2(p_{\mathrm{T}}q_{\mathrm{T}} - \mathbf{p}_{\mathrm{T}} \cdot \mathbf{q}_{\mathrm{T}})}$

Direct Slepton Pair Production $\tilde{l}^+\tilde{l}^-$

2L



$\tilde{l}^+\tilde{l}^-$ production, with 100% BR

$\tilde{l}^\pm \rightarrow l^\pm \tilde{\chi}_1^0$

Bino-like $\tilde{\chi}_1^0$, $\tilde{e}, \tilde{\mu}$ only

SM background WW dominated

Search for opposite sign lepton pairs, veto Z, jet veto, high-$E_T^{miss, rel}$, high-m_{T2}.

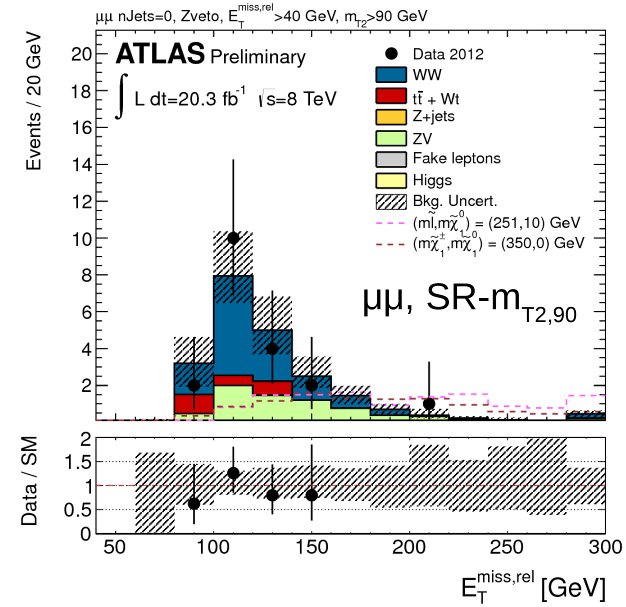
	SR-$m_{T2,90}$	SR-$m_{T2,110}$
lepton flavour	e^+e^-, $\mu^+\mu^-$, $e^\pm\mu^\mp$	
$m_{\ell\ell}$	Z veto	
$E_T^{miss,rel}$	> 40 GeV	
m_{T2}	> 90 GeV	> 110 GeV

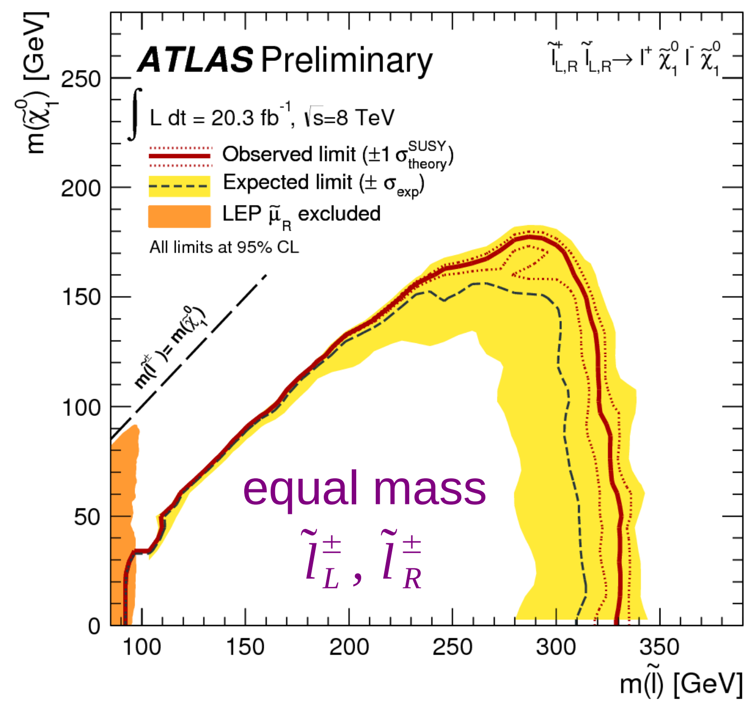
& veto jets with p_T>20 GeV, $|\eta|$<2.4 or p_T>30 GeV, 2.4<$|\eta|$<4.5

No significant excess seen

SR-$m_{T2,90}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	15	19	19	53
Background total	16.6 ± 2.3	20.7 ± 3.2	22.4 ± 3.3	59.7 ± 7.3
Observed σ_{vis}^{95} (fb)	0.44	0.51	0.47	0.81

SR-$m_{T2,110}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	4	5	4	13
Background total	6.1 ± 2.2	4.4 ± 2.0	6.3 ± 2.4	16.9 ± 6.0
Observed σ_{vis}^{95} (fb)	0.27	0.35	0.28	0.54

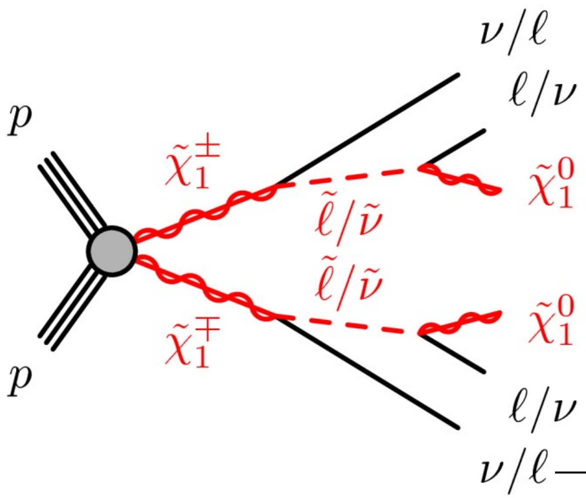




Direct Chargino Pair Production $\tilde{\chi}_1^+ \tilde{\chi}_1^-$

2L

$m(\tilde{\chi}_1^{\pm}) > m(\tilde{e}_L, \tilde{\mu}_L, \tilde{\tau}_1, \tilde{\nu}_{e,\mu,\tau}) > m(\tilde{\chi}_1^0)$



$\tilde{\chi}_1^+ \tilde{\chi}_1^-$ production, with 100% BR $\tilde{\chi}_1^{\pm} \to l^{\pm} \nu \tilde{\chi}_1^0$

Wino-like $\tilde{\chi}_1^{\pm}$, bino-like $\tilde{\chi}_1^0$

Flavour democratic

SM background WW dominated

	SR-$m_{T2,90}$	SR-$m_{T2,110}$
lepton flavour	e^+e^-, $\mu^+\mu^-$, $e^{\pm}\mu^{\mp}$	
$m_{\ell\ell}$	Z veto	
$E_T^{\mathrm{miss,rel}}$	> 40 GeV	
m_{T2}	> 90 GeV	> 110 GeV

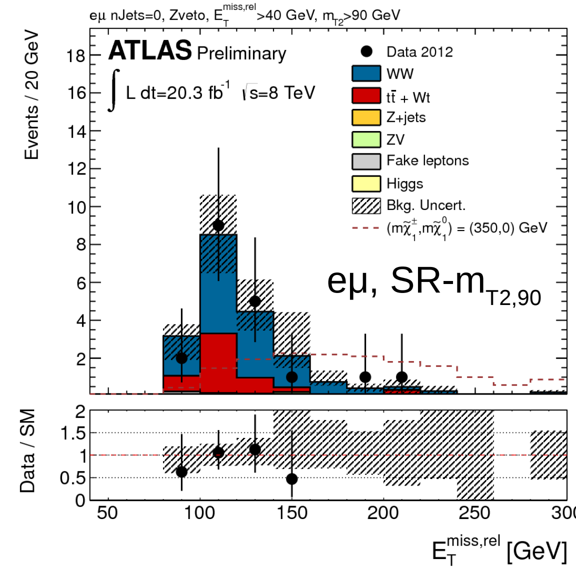
& veto jets with p_T>20 GeV, |η|<2.4 or p_T>30 GeV, 2.4<|η|<4.5

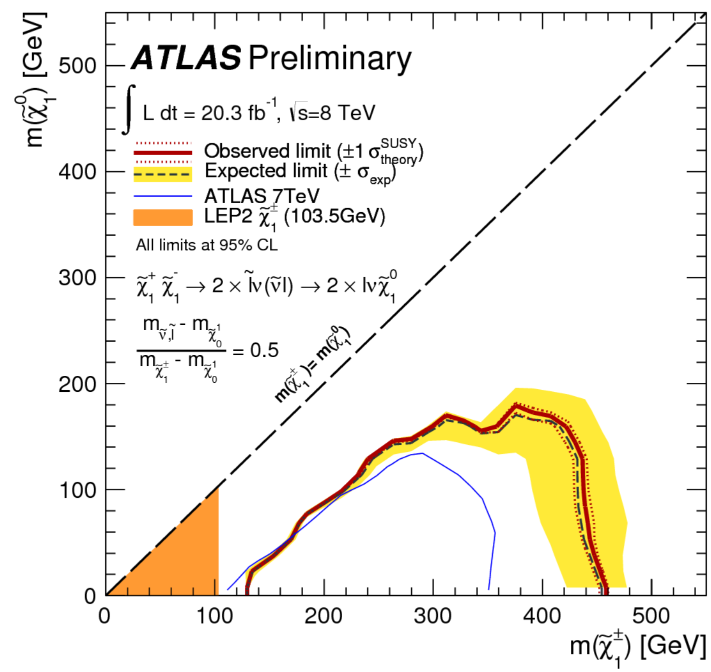
Search for opposite sign lepton pairs, veto Z, jet veto, high-$E_T^{miss, rel}$, high-m_{T2}.

No significant excess seen

SR-$m_{T2,90}$	e^+e^-	$e^{\pm}\mu^{\mp}$	$\mu^+\mu^-$	all
Observed	15	19	19	53
Background total	16.6 ± 2.3	20.7 ± 3.2	22.4 ± 3.3	59.7 ± 7.3
Observed $\sigma_{\mathrm{vis}}^{95}$ (fb)	0.44	0.51	0.47	0.81

SR-$m_{T2,110}$	e^+e^-	$e^{\pm}\mu^{\mp}$	$\mu^+\mu^-$	all
Observed	4	5	4	13
Background total	6.1 ± 2.2	4.4 ± 2.0	6.3 ± 2.4	16.9 ± 6.0
Observed $\sigma_{\mathrm{vis}}^{95}$ (fb)	0.27	0.35	0.28	0.54

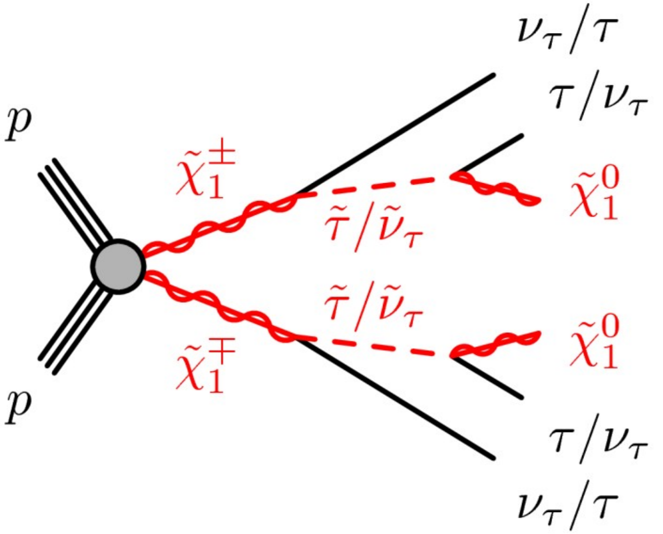




Direct Chargino Pair Production $\tilde{\chi}_1^+\tilde{\chi}_1^-$

2τ

$m(\tilde{\chi}_1^\pm) > m(\tilde{\tau}_1, \tilde{\nu}_\tau) > m(\tilde{\chi}_1^0)$



$\tilde{\chi}_1^+\tilde{\chi}_1^-$ production, with 100% BR $\tilde{\chi}_1^\pm \rightarrow \tau^\pm \nu \tilde{\chi}_1^0$

Wino-like $\tilde{\chi}_1^\pm$, bino-like $\tilde{\chi}_1^0$

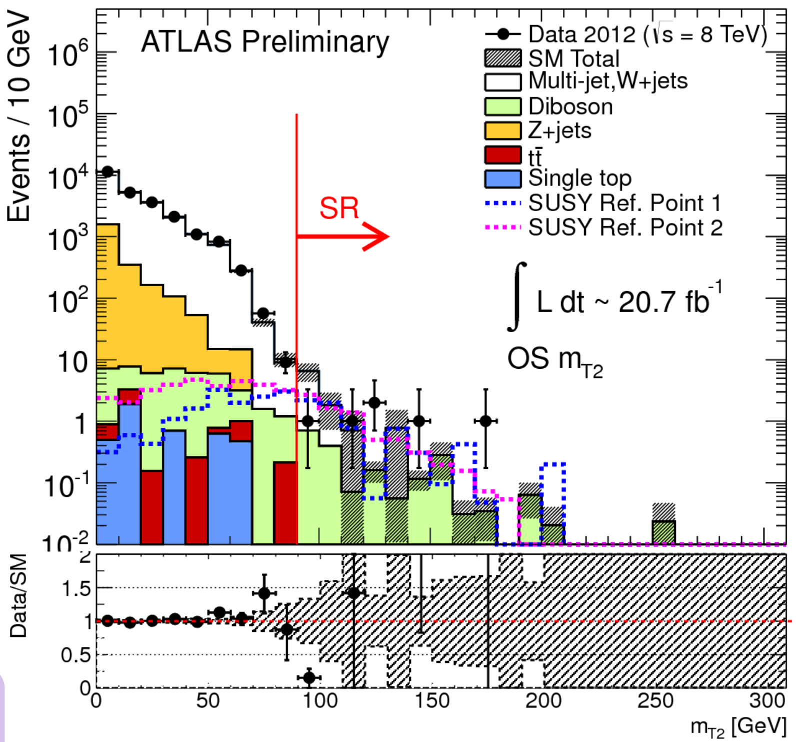
Light staus are well motivated in natural SUSY

First time studied in ATLAS

Signal region	requirements
OS m_{T2}	at least 1 OS tau pair jet veto Z-veto E_T^{miss}> 40 GeV m_{T2}> 90 GeV
OS m_{T2}-nobjet	at least 1 OS tau pair b-jet veto Z-veto E_T^{miss}> 40 GeV m_{T2}> 100 GeV

First search for $\tilde{\chi}_1^+\tilde{\chi}_1^-$ production with light staus from the LHC!

Search for $\tau^+\tau^-$, veto Z, high-E_T^{miss}, high-m_{T2}.



SM process	SR OS m_{T2}	SR OS m_{T2} -nobjet
top	0.2 ± 0.5 ± 0.1	1.6 ± 0.8 ± 1.2
Z+jets	0.28 ± 0.26 ± 0.23	0.4 ± 0.3 ± 0.3
diboson	2.2 ± 0.5 ± 0.5	2.5 ± 0.5 ± 0.9
multi-jet & W+jets	8.4 ± 2.6 ± 1.4	12 ± 3 ± 3
SM total	11.0 ± 2.7 ± 1.5	17 ± 4 ± 3
data	6	14

SM background multijet/W+jets dominated

No significant excess seen

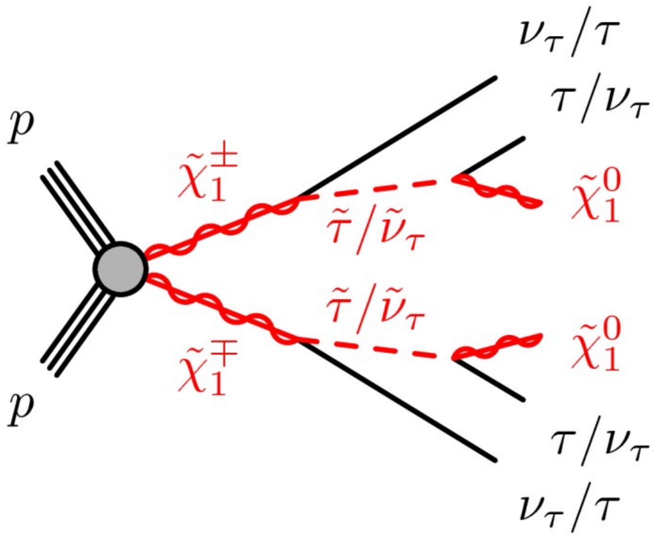
SUSY Ref Point 1: $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, $(m\tilde{\chi}_1^\pm, m\tilde{\chi}_1^0)=(250,100)$ GeV

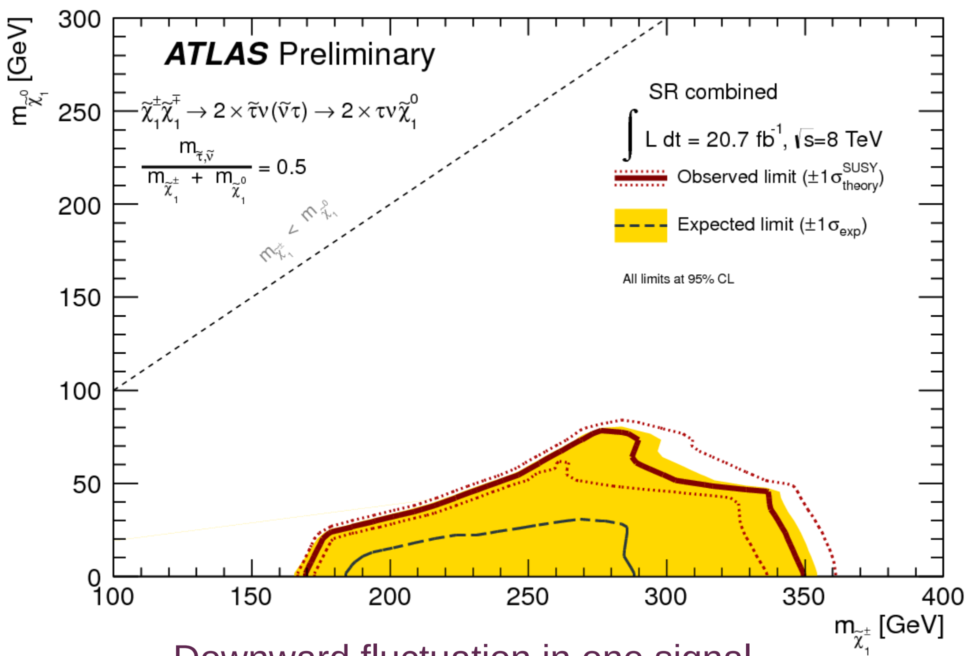
SUSY Ref Point 2: $\tilde{\chi}_1^\pm\tilde{\chi}_2^0$ production, $(m\tilde{\chi}_1^\pm, m\tilde{\chi}_1^0)=(250,50)$ GeV

Direct Chargino Pair Production $\tilde{\chi}_1^+\tilde{\chi}_1^-$

2τ

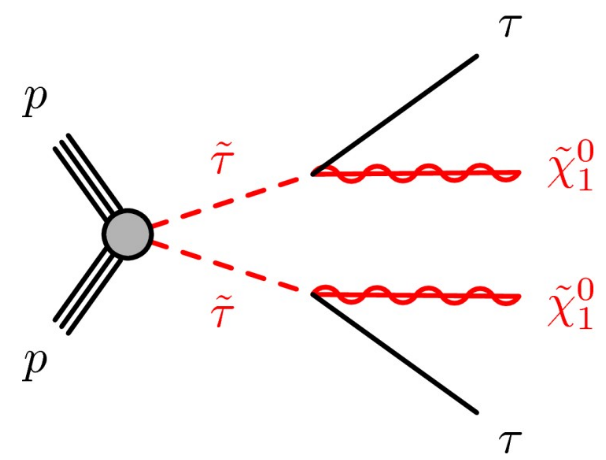
$m(\tilde{\chi}_1^\pm) > m(\tilde{\tau}_1, \tilde{\nu}_\tau) > m(\tilde{\chi}_1^0)$





Downward fluctuation in one signal region gives stronger observed limit

Direct Stau Pair Production $\tilde{\tau}^+\tilde{\tau}^-$



$\tilde{\tau}^+\tilde{\tau}^-$ production, with 100% BR $\tilde{\tau}^\pm \to \tau^\pm\tilde{\chi}_1^0$

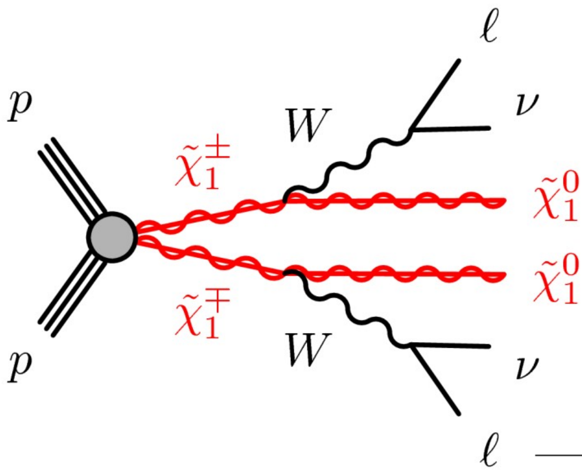
Use 2τ signal regions to probe direct stau pair production

Set upper limit on cross-section

For a $\tilde{\tau}$ mass 140 GeV, $\tilde{\chi}_1^0$ mass 10 GeV
Theoretical cross-section 0.04 pb
Upper limit on cross-section 0.17 pb

Direct Chargino Pair Production $\tilde{\chi}_1^+ \tilde{\chi}_1^-$

$m(\tilde{l}, \tilde{\nu}) > m(\tilde{\chi}_1^\pm) > m(\tilde{\chi}_1^0)$



$\tilde{\chi}_1^+ \tilde{\chi}_1^-$ production, with 100% BR $\tilde{\chi}_1^\pm \rightarrow W^\pm \tilde{\chi}_1^0$
W decays with SM BR

Wino-like $\tilde{\chi}_1^\pm$, bino-like $\tilde{\chi}_1^0$

First search for $\tilde{\chi}_1^+ \tilde{\chi}_1^-$ production via W bosons from the LHC!

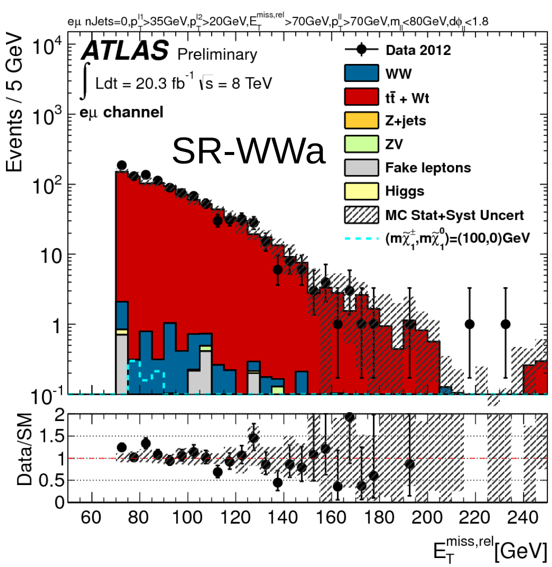
Search for $e^+\mu^-$, high-$E_T^{miss,rel}$ or high-m_{T2}.

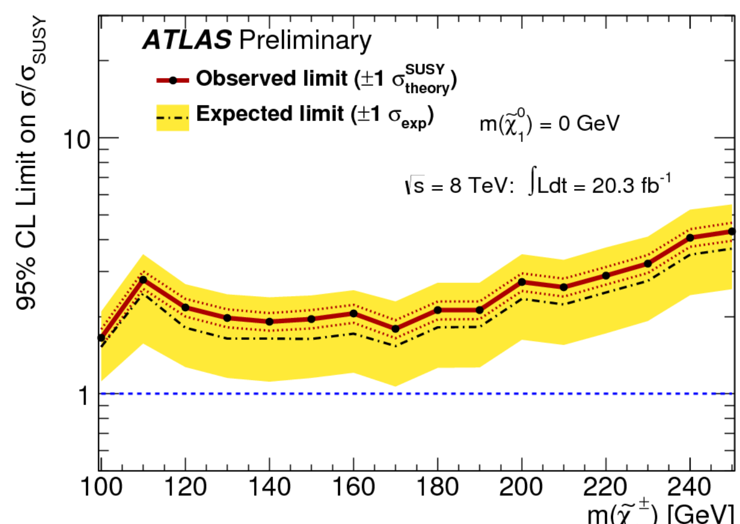
SM background top dominated

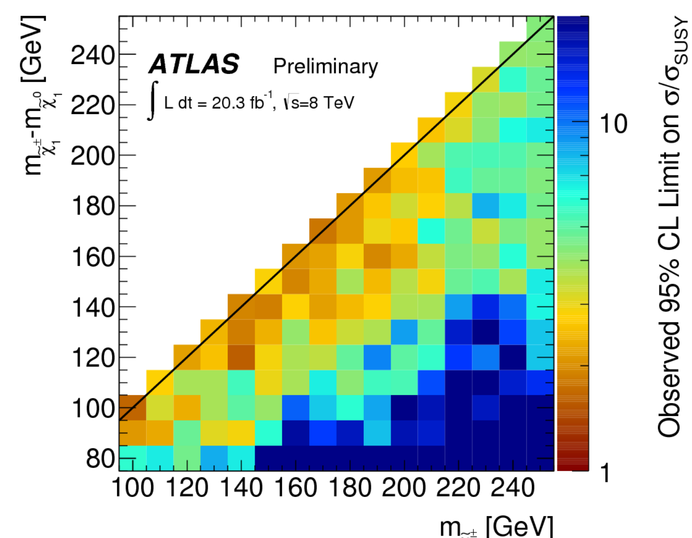
	SR-WWa	SR-WWb	SR-WWc
lepton flavour	$e^\pm\mu^\mp$		
$p_T^{\ell 1}$	> 35 GeV		
$p_T^{\ell 2}$	> 20 GeV		
$m_{\ell\ell}$	< 80 GeV	< 130 GeV	—
$p_{T,\ell\ell}$	> 70 GeV	< 170 GeV	< 190 GeV
$\Delta\phi_{\ell\ell}$	< 1.8 rad		
$E_T^{miss,rel}$	> 70 GeV	—	
m_{T2}	—	> 90 GeV	> 100 GeV

	SR-WWa	SR-WWb	SR-WWc
Observed	123	16	9
Background total	117.9 ± 14.6	13.6 ± 2.3	7.4 ± 1.5
Observed σ^{95}_{vis} (fb)	1.94	0.58	0.43
Expected σ^{95}_{vis} (fb)	$1.77^{+0.66}_{-0.49}$	$0.51^{+0.21}_{-0.15}$	$0.37^{+0.18}_{-0.11}$

No significant excess seen



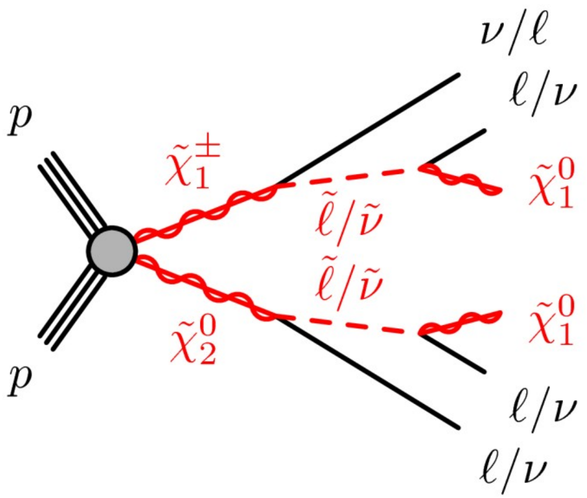




Direct Chargino-Neutralino Production $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

3L

$m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0) > m(\tilde{e}_L, \tilde{\mu}_L, \tilde{\tau}_1, \tilde{\nu}_{e,\mu,\tau}) > m(\tilde{\chi}_1^0)$



$\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production,

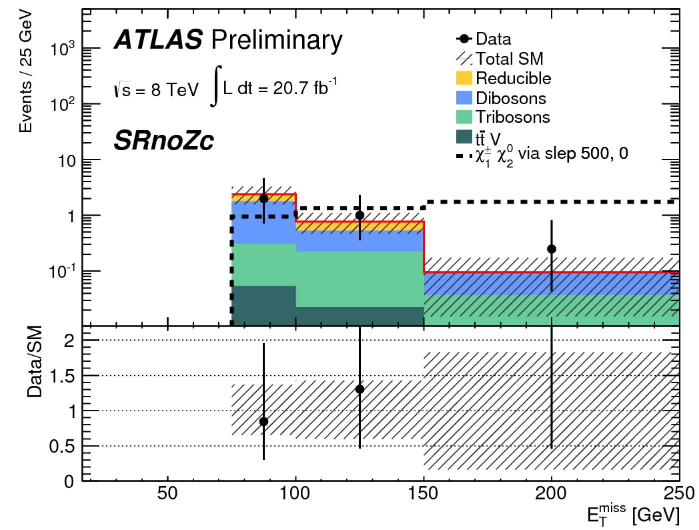
with 50% BR $\tilde{\chi}_2^0 \to l^+ l^- \tilde{\chi}_1^0$

50% BR $\tilde{\chi}_2^0 \to \nu\nu\tilde{\chi}_1^0$

Flavour democratic

Wino-like $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$, bino-like $\tilde{\chi}_1^0$

→ mass degenerate $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0$



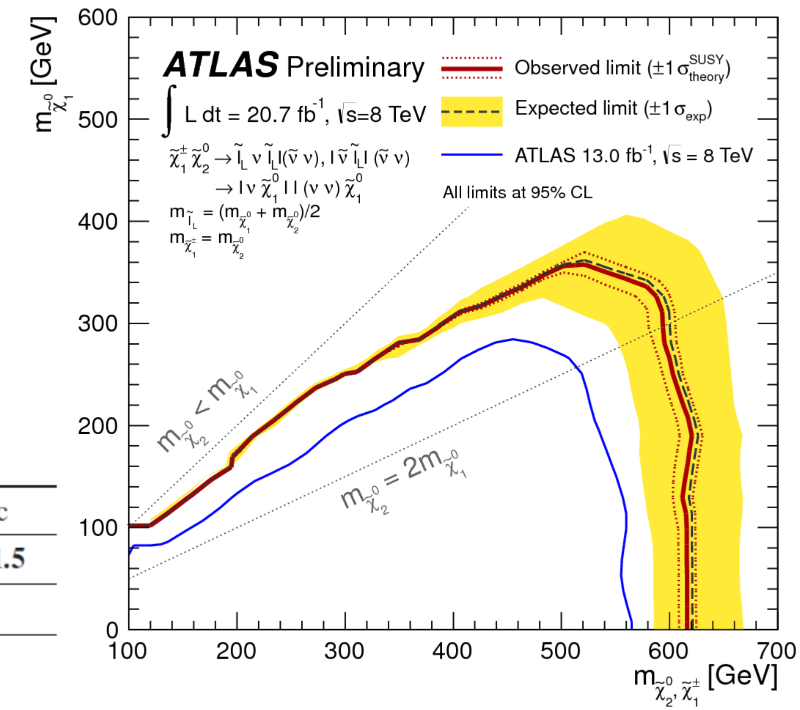
Search for 3l (e,μ), SFOS, request/veto Z, high-E_T^{miss}, high-m_T.

SM background
WZ/top dominated

Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
m_{SFOS} [GeV]	<60	60–81.2	<81.2 or >101.2	81.2–101.2	81.2–101.2	81.2–101.2
E_T^{miss} [GeV]	>50	>75	>75	75–120	75–120	>120
m_T [GeV]	–	–	>110	<110	>110	>110
p_T 3rd ℓ [GeV]	>10	>10	>30	>10	>10	>10
SR veto	SRnoZc	SRnoZc	–	–	–	–

No significant excess seen

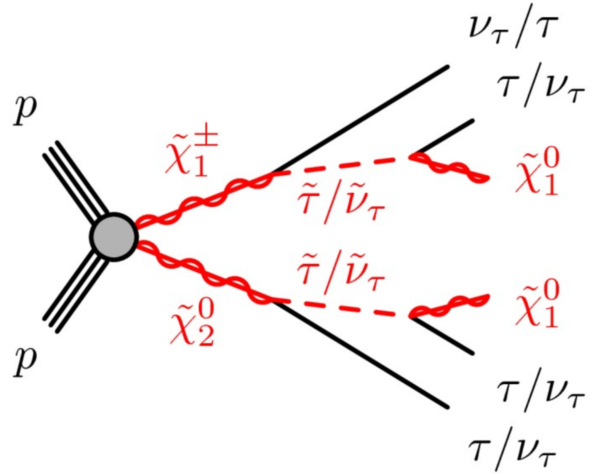
Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
Σ SM	**96 ± 19**	**29 ± 6**	**4.4 ± 1.8**	**249 ± 35**	**22 ± 5**	**6.3 ± 1.5**
Data	**101**	**32**	**5**	**273**	**23**	**6**
$\sigma_{visible}$ excluded (obs) [fb]	2.02	0.87	0.33	4.04	0.67	0.31



Direct Chargino-Neutralino Production $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}$

2τ

$m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^{0}) > m(\tilde{\tau}_{1}, \tilde{\nu}_{\tau}) > m(\tilde{\chi}_1^{0})$



Light staus are well motivated in natural SUSY
First time studied in ATLAS

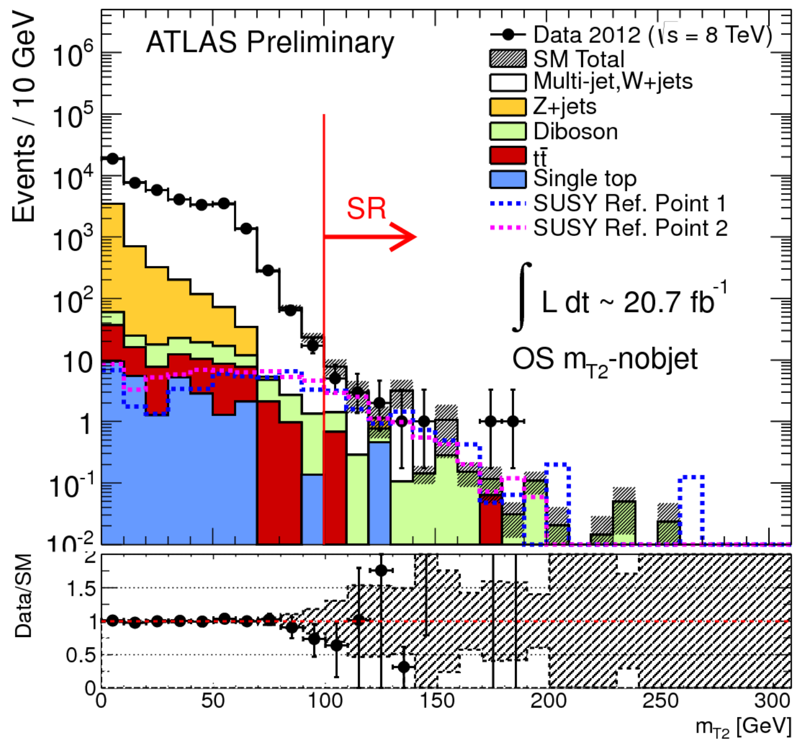
Search for $\tau^+\tau^-$,
veto Z,
high-E_T^{miss}, high-m_{T2}.

Wino-like $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^{0}$, bino-like $\tilde{\chi}_1^{0}$

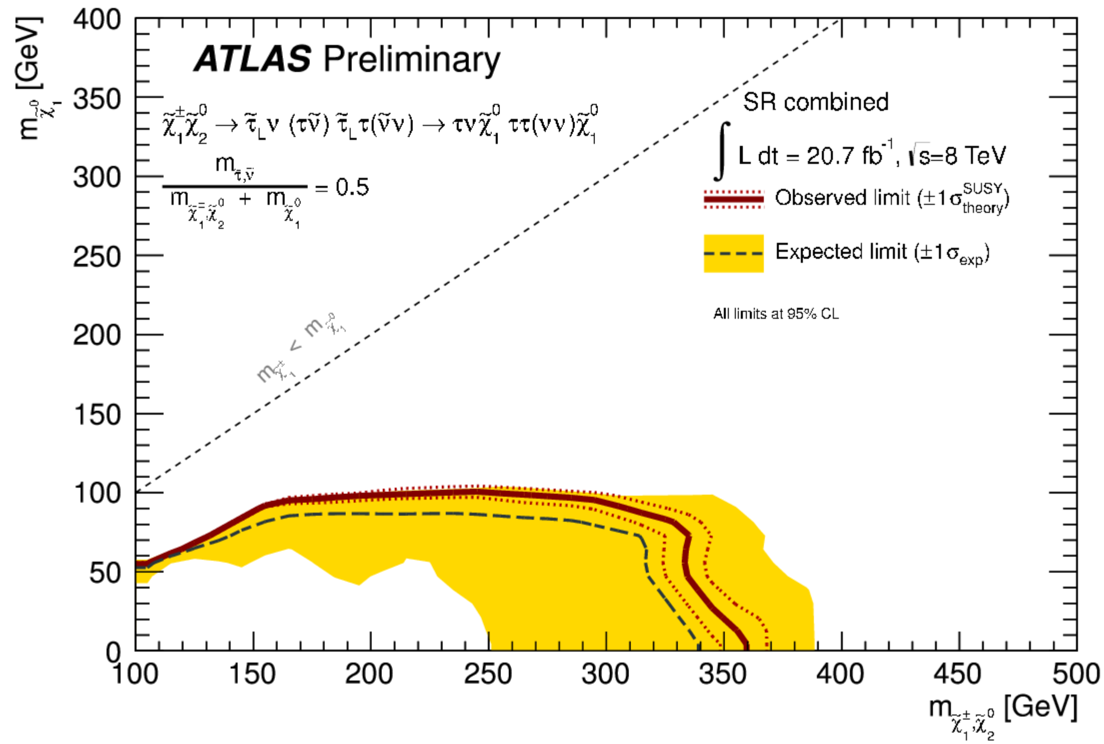
→ mass degenerate $\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^{0}$

Same signal regions as slide 7

No significant excess seen



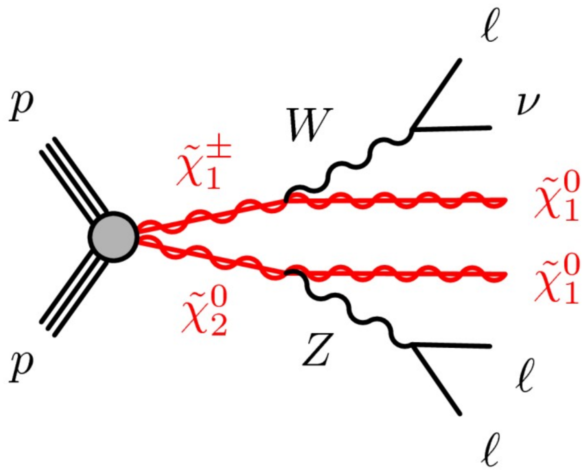
SUSY Ref Point 1: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}$ production, $(m\tilde{\chi}_1^{\pm}, m\tilde{\chi}_1^{0}) = (250, 100)$ GeV
SUSY Ref Point 2: $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^{0}$ production, $(m\tilde{\chi}_1^{\pm}, m\tilde{\chi}_1^{0}) = (250, 50)$ GeV



Direct Chargino-Neutralino Production $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

3L

$m(\tilde{l},\tilde{\nu}) > m(\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0) > m(\tilde{\chi}_1^0)$



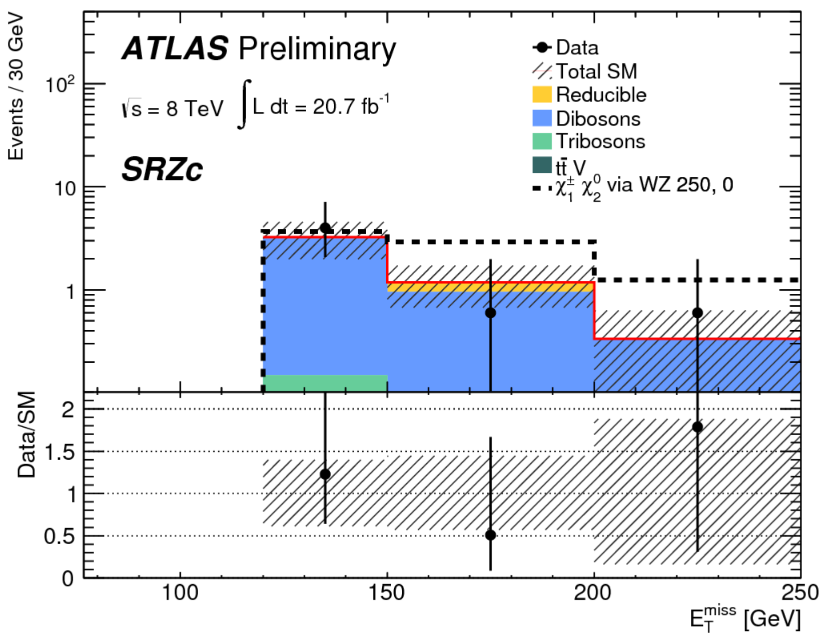
Charginos/neutralinos decay via SM gauge bosons

Wino-like $\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$, bino-like $\tilde{\chi}_1^0$

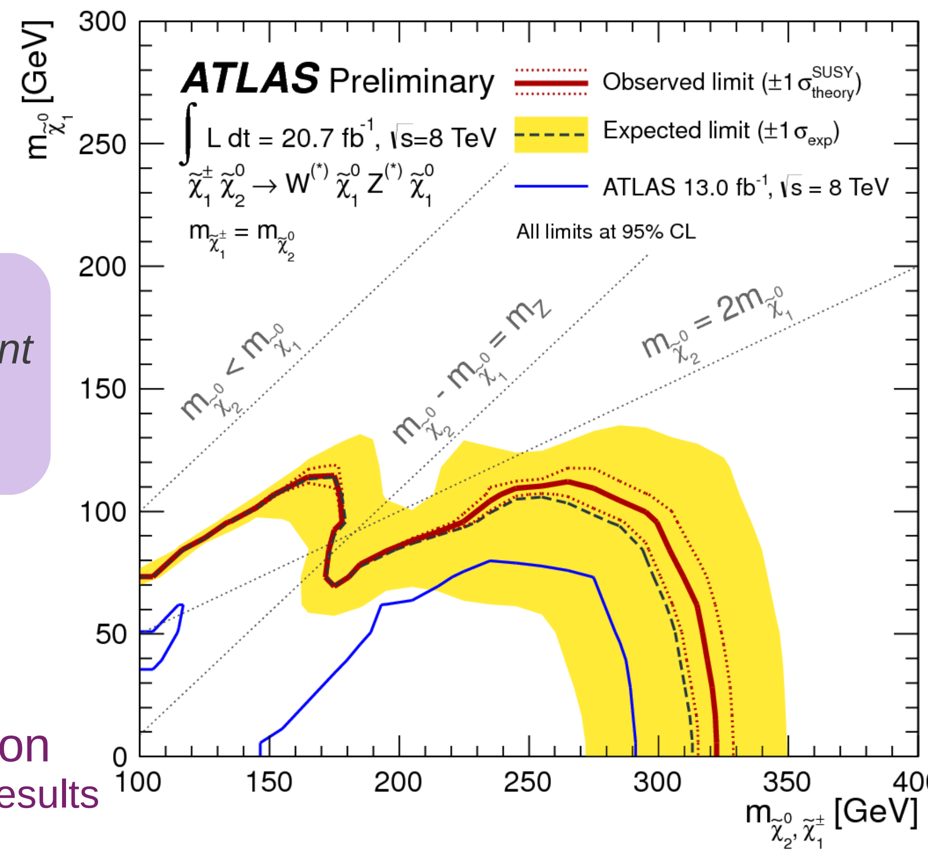
→ mass degenerate $\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$

Search for 3l (e,μ), SFOS, veto or select Z, high-E_T^{miss}, high-m_T.

Same signal regions as slide 10



No significant excess seen



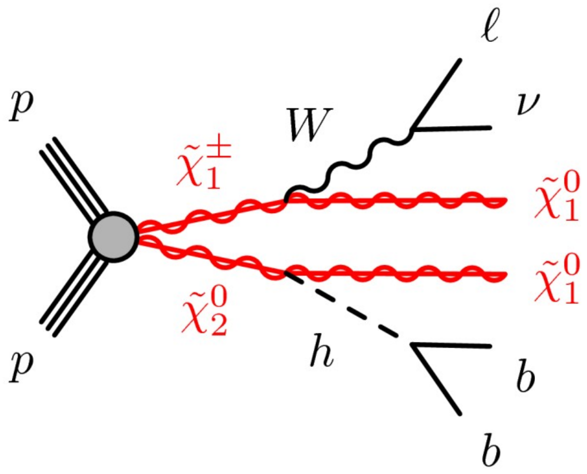
Improved limits in challenging WZ* region

compared to 13 fb^{-1} results

Direct Chargino-Neutralino Production $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

New for SUSY13!

$m(\tilde{l},\tilde{\nu}) > m(\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0) > m(\tilde{\chi}_1^0)$



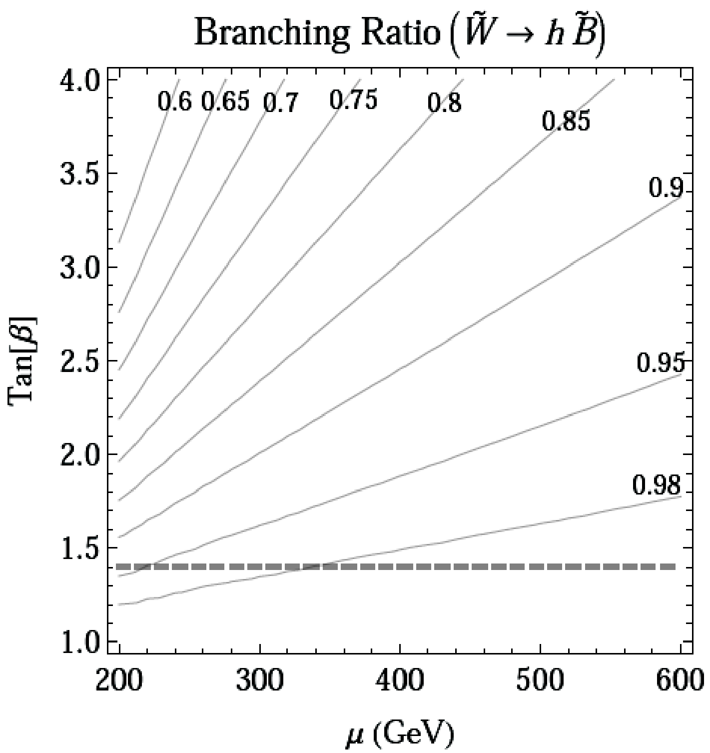
$\tilde{\chi}_1^{\pm}$ decays 100% via W

$\tilde{\chi}_2^0$ decays 100 % via 125 GeV SM-like lightest higgs

$\Delta m(\tilde{\chi}_2^0,\tilde{\chi}_1^0) > 125$ GeV

Wino-like $\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$, bino-like $\tilde{\chi}_1^0$

→ mass degenerate $\tilde{\chi}_1^{\pm},\tilde{\chi}_2^0$

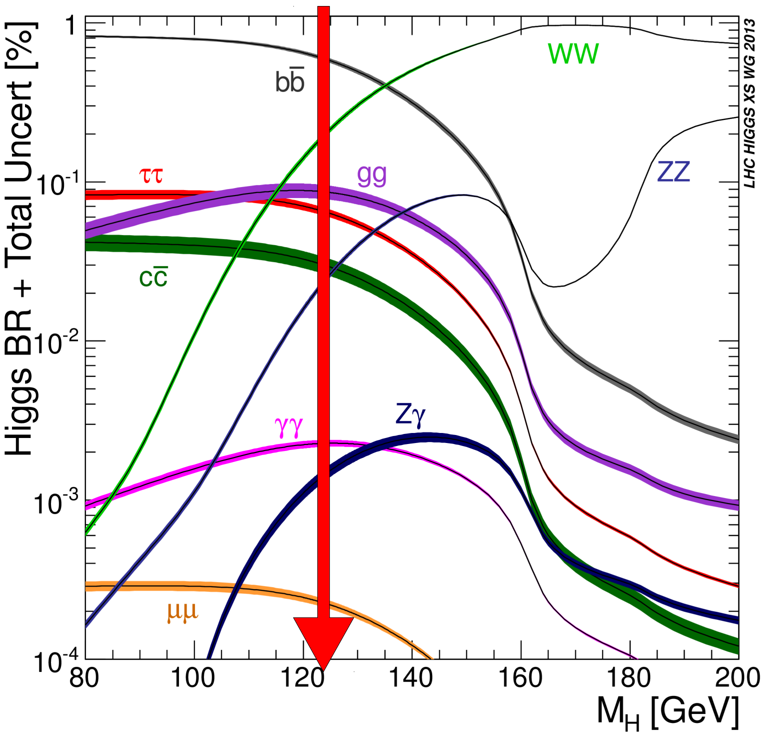


JHEP 1210 (2012) 065

Where kinematically allowed, $\tilde{\chi}_2^0 \to h\tilde{\chi}_1^0$ could be a significant fraction of the BR

For 175 GeV wino, and bino <10 GeV (M_1 and M_2 varied)

125 GeV SM-like lightest higgs decays to bottom quarks with highest BR



Direct Chargino-Neutralino Production $\tilde{\chi}_1^\pm \tilde{\chi}_2^0$

New for SUSY13!

1L

$$m(\tilde{l}, \tilde{\nu}) > m(\tilde{\chi}_1^\pm, \tilde{\chi}_2^0) > m(\tilde{\chi}_1^0)$$

	SRA	SRB	CR1	CR2	VR0	VR1	VR2
Number of b-tagged jets	2	2	1	2	0	1	2
m_T (GeV)	100–130	> 130	> 100	40–80	> 100	40-100	80–100

& E_T^{miss} > 100 GeV, m_{CT} > 160 GeV, m_{bb} > 50 GeV

$$m_{CT}^2 = \left(E_T^{b_1} + E_T^{b_2}\right)^2 - \left|\mathbf{p}_T^{b_1} - \mathbf{p}_T^{b_2}\right|^2$$

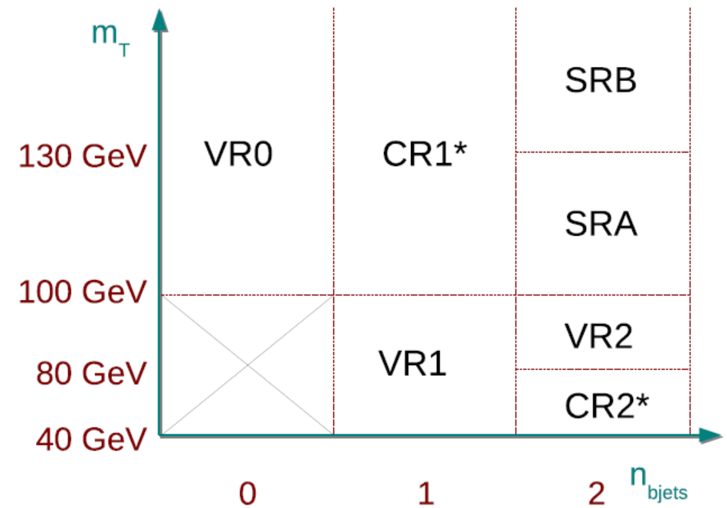
model-independent limits, SRA/B consider only m_{bb} 105–135 GeV
model-dependent fit, SRA/B consider m_{bb} > 50 GeV

Search for 1l (e,μ),
2 b-tagged jets consistent with higgs decay,
high-E_T^{miss}, high-m_T, high-m_{CT}

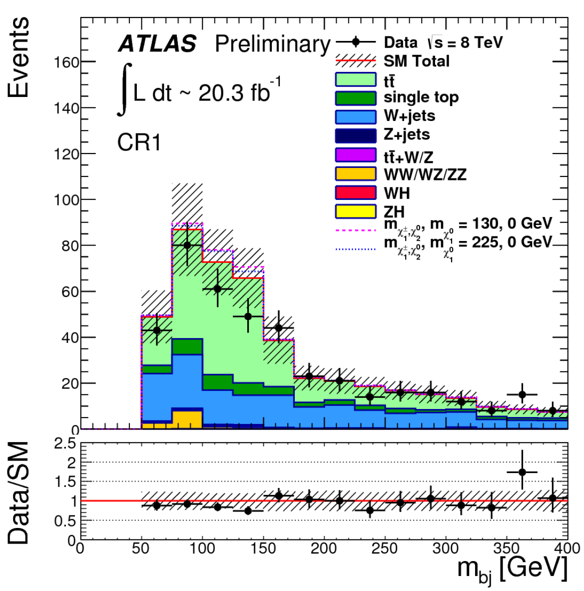
m_{CT} targets ttbar
m_T targets W+jets

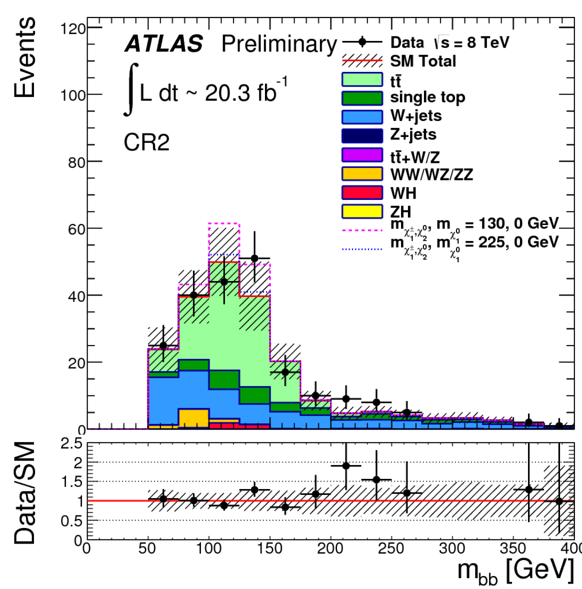
m_{CT} > 160 GeV
m_{bb} > 50 GeV
$\not{E}_T$ > 100 GeV

* indicates that only the m_{bb} sidebands are used to avoid signal contamination



Ttbar- and W+jets-rich CR1 and CR2
Event yields in CR fitted using profile likelihood algorithm
→ simultaneously determines signal and background contributions in SR





Fit using 8 bins in m_{bb}
→ exclude m_{bb} 105–135 GeV to avoid signal contamination
(for background only fit, not for discovery or exclusion fit)

Single top, WH, ZH, Z+jets, dibosons, ttbar+W/Z backgrounds using MC simulation

Direct Chargino-Neutralino Production $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$

New for SUSY13!

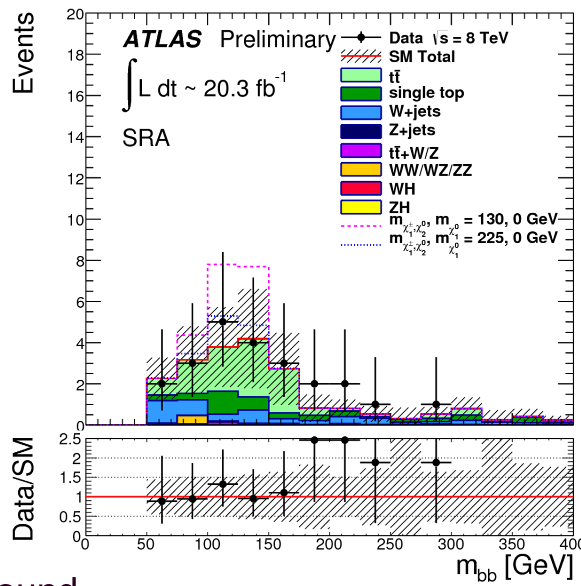
1L

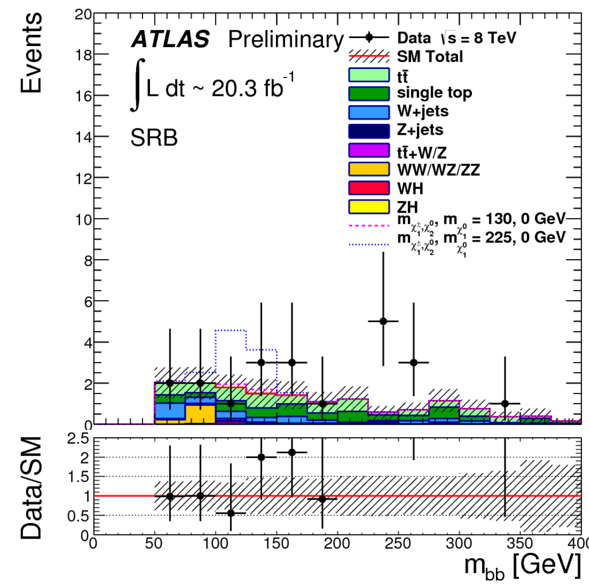
$m(\tilde{l}, \tilde{\nu}) > m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_2^0) > m(\tilde{\chi}_1^0)$

targets $m(\tilde{\chi}_2^0)-m(\tilde{\chi}_1^0)$ <175 GeV >175 GeV

m_{bb} 105 − 135 GeV	SRAh	SRBh
Observed events	4	2
Background estimate		
$t\bar{t}$	2.9 ± 2.8	1.0 ± 0.6
$W+$jets	0.7 ± 0.4	0.3 ± 0.2
Single top	1.6 ± 1.3	0.6 ± 0.4
Z+jets	$0.01^{+0.02}_{-0.01}$	$0.00^{+0.01}_{-0.00}$
Diboson (VV)	$0.01^{+0.05}_{-0.01}$	$0.05^{+0.07}_{-0.05}$
WH	0.18 ± 0.10	0.12 ± 0.07
$t\bar{t}+V$	0.01 ± 0.01	0.11 ± 0.06
Total	5.4 ± 3.1	2.1 ± 0.7

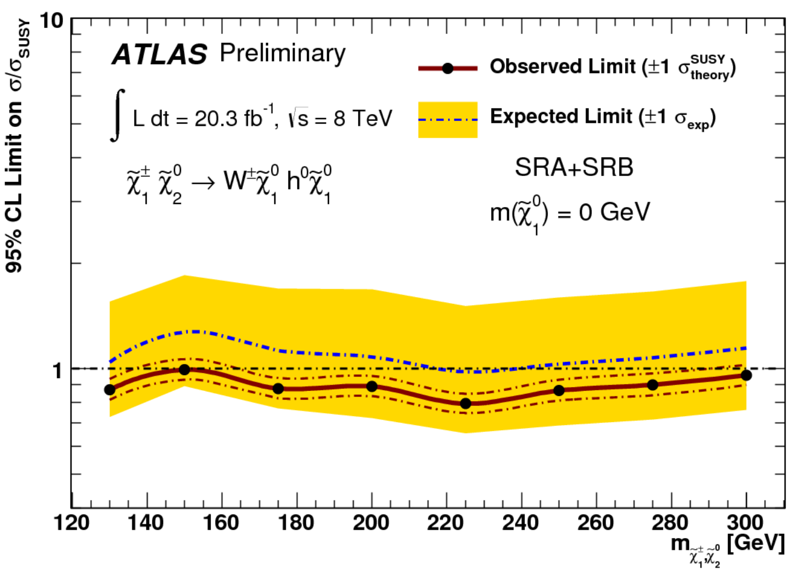
	SRAh	SRBh
Observed σ^{95}_{vis} (Pseudo-experiments)	0.34 fb	0.21 fb
Observed S^{95}_{obs} (Pseudo-experiments)	6.9	4.4





No significant excess seen

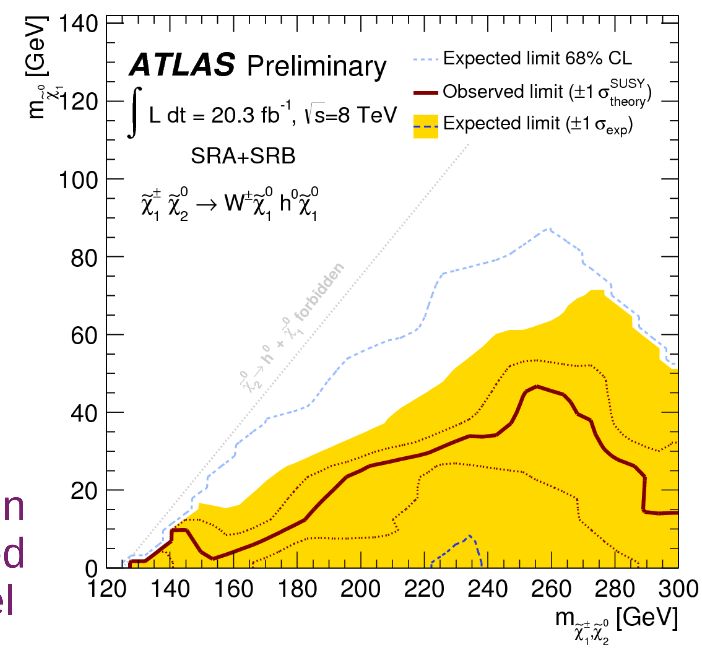
SM background top dominated



First search for $\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0$ production via higgs from the LHC!

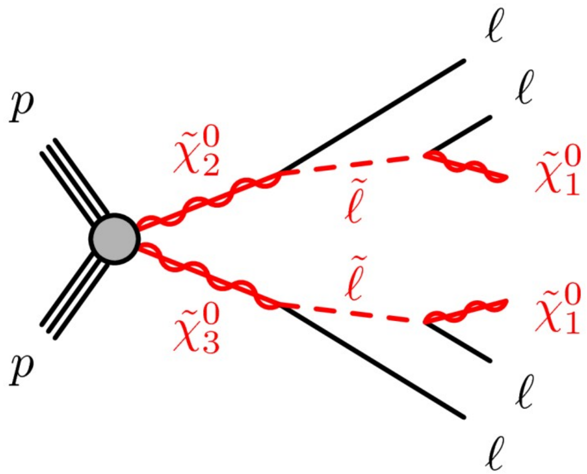
Set upper limit on cross-section for massless LSP

Set limit in simplified model



Direct Neutralino Pair Production $\tilde{\chi}^0_2 \tilde{\chi}^0_3$

$m(\tilde{\chi}^0_2) > m(\tilde{e}_R, \tilde{\mu}_R) > m(\tilde{\chi}^0_1)$



Higgsino-like $\tilde{\chi}^0_2, \tilde{\chi}^0_3$, bino-like $\tilde{\chi}^0_1$

→ mass degenerate $\tilde{\chi}^0_2, \tilde{\chi}^0_3$

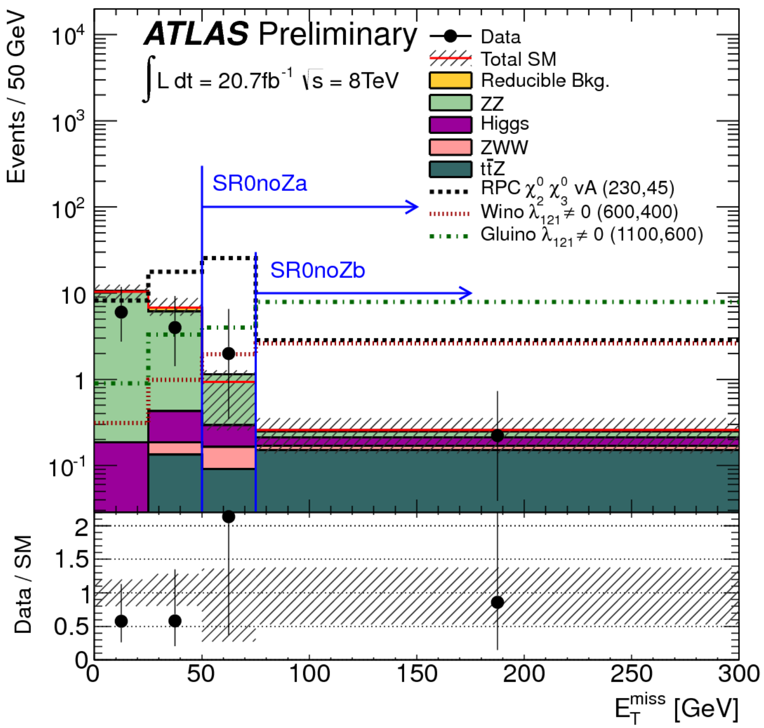
First time studied in ATLAS

Search for 4l (e,μ), veto Z, high-E_T^{miss}.

SR	N($\ell = e,\mu$)	N(τ)	Z Candidate	E_T^{miss}[GeV]
SR0noZa	≥4	≥0	extended veto	>50
SR0noZb	≥4	≥0	extended veto	>75
SR1noZ	=3	≥1	extended veto	>100
SR0Z	≥4	≥0	request	>75
SR1Z	=3	≥1	request	>100

SR0noZa targets N2N3 production.

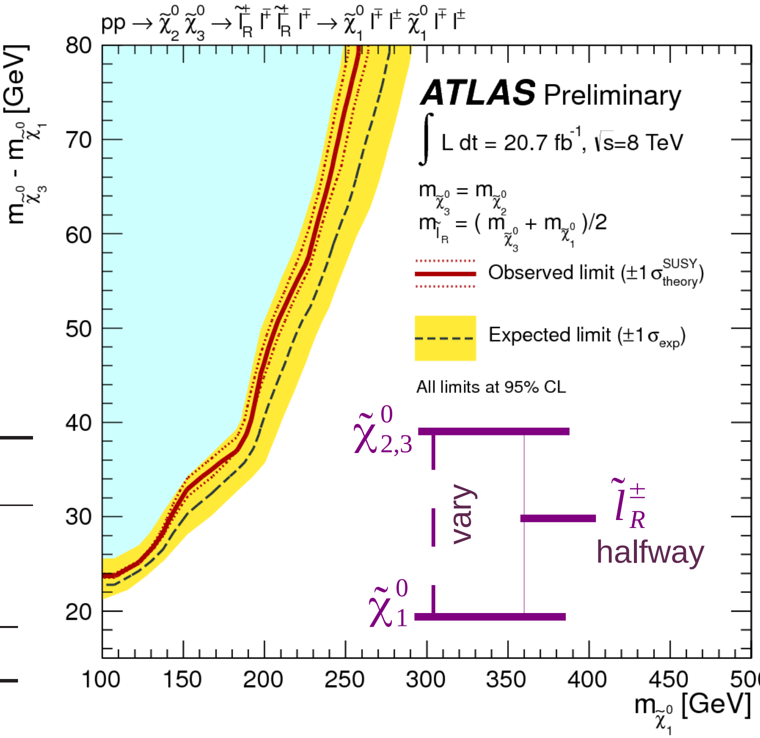
Tighter signal regions + 1-2 taus also studied



SM background ZZ dominated

No significant excess seen

Sample	SR0noZa
Total Bkg.	1.7 ± 0.8
Data	2
$\sigma_{visible}$ Excluded (obs) [fb]	0.23



Summary

Natural SUSY favours light gauginos/higgsinos

Electroweak/3rd gen. SUSY could be the dominant SUSY cross-section at the LHC

Search for direct slepton/chargino/neutralino production in ATLAS 8 TeV dataset using clean, leptonic final states

No significant excess seen in electroweak SUSY searches

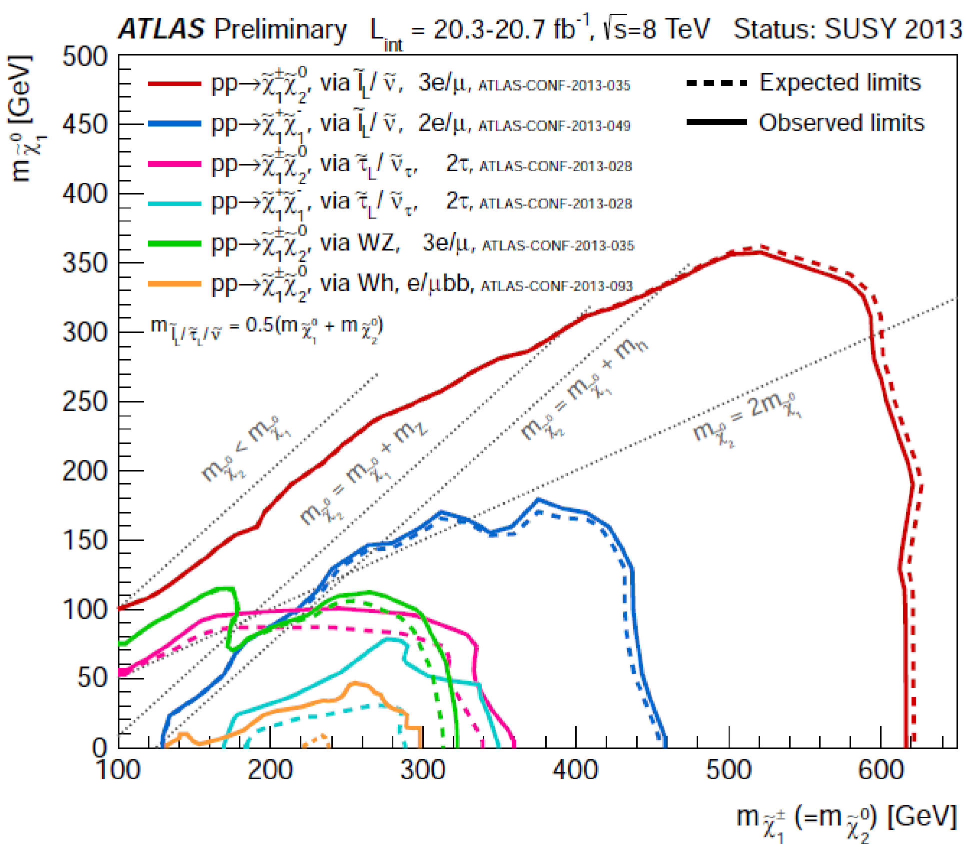
Stringent limits set in simplified models

including scenarios with decays via staus, gauge bosons or higgs

8 TeV analysis has been fruitful!

Next... increase sensitivity, explore new channels, probe more parameter space

Prepare for $\sqrt{s}$ = 13 TeV LHC run!



2 lepton final states (e,μ)
ATLAS-CONF-2013-049

Standard Model Background Modelling

Irreducible
WW, top, ZV (ZZ, WZ)
  Normalised to data in Control Regions
Other, MC simulation

Reducible
1 or 2 leptons from heavy flavour decays, conversion or mis-id
  Data-driven "matrix method"

$$N_B^{SR} = \left[\frac{N^{CR} - N^{CR}_{other}}{N^{CR}_{B,MC}}\right] \times N^{SR}_{B,MC}$$

Normalisation factors in blue

SR	SR-$m_{T2,90}$	SR-$m_{T2,110}$	SR-WWa	SR-WWb	SR-WWc
WW CR	1.12 ± 12.5%				
lepton flavour	$e^{\pm}\mu^{\mp}$		$e^{\pm}\mu^{\mp}$		
$m_{\ell\ell}$	Z veto		—		
$\Delta\phi_{\ell\ell}$	—		< 1.8 rad		
$E_T^{miss,rel}$	> 40 GeV		< 70 GeV	—	
m_{T2}	50–90 GeV		—	< 90 GeV	
Top CR	1.05 ± 4.8%				
b-tagged jets	≥ 1		≥ 1		
signal jets	≥ 2		≥ 1		
lepton flavour	$e^+e^-, \mu^+\mu^-, e^{\pm}\mu^{\mp}$		$e^{\pm}\mu^{\mp}$		
$m_{\ell\ell}$	Z veto		< 80 GeV	< 130 GeV	
$p_{T,\ell\ell}$	—		> 70 GeV	< 170 GeV	< 190 GeV
$\Delta\phi_{\ell\ell}$	—		< 1.8 rad		
$E_T^{miss,rel}$	> 40 GeV		> 70 GeV	—	
m_{T2}	—		—	> 90 GeV	> 100 GeV
ZV CR	0.96-1.06 ± 15-16%		not defined		
lepton flavour	$e^+e^-, \mu^+\mu^-$				
$m_{\ell\ell}$	Z select				
$E_T^{miss,rel}$	> 40 GeV				
m_{T2}	> 90 GeV	> 110 GeV			

2 lepton final states (e,μ)
ATLAS-CONF-2013-049

SR definitions

	SR-$m_{T2,90}$	SR-$m_{T2,110}$	SR-WWa	SR-WWb	SR-WWc
lepton flavour	e^+e^-, $\mu^+\mu^-$, $e^\pm\mu^\mp$		$e^\pm\mu^\mp$		
$p_T^{\ell 1}$	—		> 35 GeV		
$p_T^{\ell 2}$	—		> 20 GeV		
$m_{\ell\ell}$	Z veto		< 80 GeV	< 130 GeV	—
$p_{T,\ell\ell}$	—		> 70 GeV	< 170 GeV	< 190 GeV
$\Delta\phi_{\ell\ell}$	—			< 1.8 rad	
$E_T^{\text{miss,rel}}$	> 40 GeV		> 70 GeV	—	
m_{T2}	> 90 GeV	> 110 GeV	—	> 90 GeV	> 100 GeV

SR-m_{T2} also vetos jets with p_T>20 GeV, |η|<2.4 or p_T>30 GeV, 2.4<|η|<4.5

Systematics

	SR-$m_{T2,90}$			SR-$m_{T2,110}$			SR-WW ($e^\pm\mu^\mp$)		
	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$	e^+e^-	$\mu^+\mu^-$	$e^\pm\mu^\mp$	a	b	c
MC statistics	7.7	6.1	7.5	12	8.2	14	2.9	8.5	11
Jet	9.5	17	12	14	13	6.8	3.1	5.0	7.0
Lepton	3.9	0.5	4.8	5.2	0.5	1.2	1.1	1.7	5.3
Soft term	1.9	3.2	6.0	3.0	1.0	0.7	1.0	4.6	4.3
b-tagging	0.2	0.2	0.2	0.2	0.3	0.2	0.4	0.7	0.5
Fake lepton	1.0	0.7	0.6	1.5	1.9	3.0	0.1	1.2	1.2
Luminosity	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
Theory & modelling	9.7	9.4	11	32	36	43	12	14	14
Total	14	15	16	36	38	45	12	17	20

Results

	SR-WWa	SR-WWb	SR-WWc
Observed	123	16	9
Background total	117.9 ± 14.6	13.6 ± 2.3	7.4 ± 1.5
Top	15.2 ± 6.6	2.7 ± 1.1	1.0 ± 0.7
WW	98.6 ± 14.6	10.2 ± 2.1	5.9 ± 1.3
ZV ($V = W$ or Z)	3.4 ± 0.8	$0.26^{+0.31}_{-0.26}$	0.29 ± 0.14
Higgs	0.76 ± 0.14	0.21 ± 0.06	0.10 ± 0.04
fake	$0.02^{+0.33}_{-0.02}$	$0.26^{+0.30}_{-0.26}$	$0.12^{+0.17}_{-0.12}$
Signal expectation			
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (100, 0)$ GeV	31	N/A	N/A
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (140, 20)$ GeV	N/A	8.2	N/A
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (200, 0)$ GeV	N/A	N/A	3.3
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (110, 113)$ GeV	18	4.3	N/A
Observed σ^{95}_{vis} (fb)	1.94	0.58	0.43
Expected σ^{95}_{vis} (fb)	$1.77^{+0.66}_{-0.49}$	$0.51^{+0.21}_{-0.15}$	$0.37^{+0.18}_{-0.11}$

Results

SR-$m_{T2,90}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	15	19	19	53
Background total	16.6 ± 2.3	20.7 ± 3.2	22.4 ± 3.3	59.7 ± 7.3
WW	9.3 ± 1.6	14.1 ± 2.2	12.6 ± 2.0	36.1 ± 5.1
ZV ($V = W$ or Z)	6.3 ± 1.5	0.8 ± 0.3	7.3 ± 1.7	14.4 ± 3.2
Top	$0.9^{+1.1}_{-0.9}$	5.6 ± 2.1	2.5 ± 1.8	8.9 ± 3.9
Higgs	0.11 ± 0.04	0.19 ± 0.05	0.08 ± 0.04	0.38 ± 0.08
Fake	$0.00^{+0.18}_{-0.00}$	$0.00^{+0.14}_{-0.00}$	$0.00^{+0.15}_{-0.00}$	$0.00^{+0.28}_{-0.00}$
Signal expectation				
$(m_{\tilde\ell}, m_{\tilde\chi_1^0}) = (191, 90)$ GeV	21.6	0	21.6	43.2
$(m_{\tilde\ell}, m_{\tilde\chi_1^0}) = (251, 10)$ GeV	12.2	0	12.5	24.7
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (350, 0)$ GeV	11.7	16.6	10.5	38.8
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (425, 75)$ GeV	4.3	6.7	4.4	15.4
Observed σ^{95}_{vis} (fb)	0.44	0.51	0.47	0.81
Expected σ^{95}_{vis} (fb)	$0.50^{+0.22}_{-0.15}$	$0.57^{+0.25}_{-0.17}$	$0.58^{+0.25}_{-0.17}$	$1.00^{+0.41}_{-0.28}$

SR-$m_{T2,110}$	e^+e^-	$e^\pm\mu^\mp$	$\mu^+\mu^-$	all
Observed	4	5	4	13
Background total	6.1 ± 2.2	4.4 ± 2.0	6.3 ± 2.4	16.9 ± 6.0
WW	2.7 ± 1.5	3.6 ± 2.0	2.9 ± 1.6	9.1 ± 4.9
ZV ($V = W$ or Z)	2.7 ± 1.4	0.2 ± 0.1	3.4 ± 1.8	6.3 ± 3.3
Top	0.7 ± 0.7	0.6 ± 0.4	0.0 ± 0.0	1.3 ± 1.0
Higgs	0.05 ± 0.03	0.12 ± 0.04	0.05 ± 0.02	0.22 ± 0.05
Fake	$0.00^{+0.09}_{-0.00}$	$0.00^{+0.13}_{-0.00}$	$0.00^{+0.12}_{-0.00}$	$0.00^{+0.28}_{-0.00}$
Signal expectation				
$(m_{\tilde\ell}, m_{\tilde\chi_1^0}) = (191, 90)$ GeV	12.3	0	12.0	24.3
$(m_{\tilde\ell}, m_{\tilde\chi_1^0}) = (251, 10)$ GeV	10.5	0	11.2	21.7
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (350, 0)$ GeV	9.5	14.0	8.7	32.2
$(m_{\tilde\chi_1^\pm}, m_{\tilde\chi_1^0}) = (425, 75)$ GeV	3.7	1.1	3.8	8.5
Observed σ^{95}_{vis} (fb)	0.27	0.35	0.28	0.54
Expected σ^{95}_{vis} (fb)	$0.33^{+0.16}_{-0.10}$	$0.33^{+0.16}_{-0.09}$	$0.33^{+0.16}_{-0.10}$	$0.62^{+0.23}_{-0.16}$

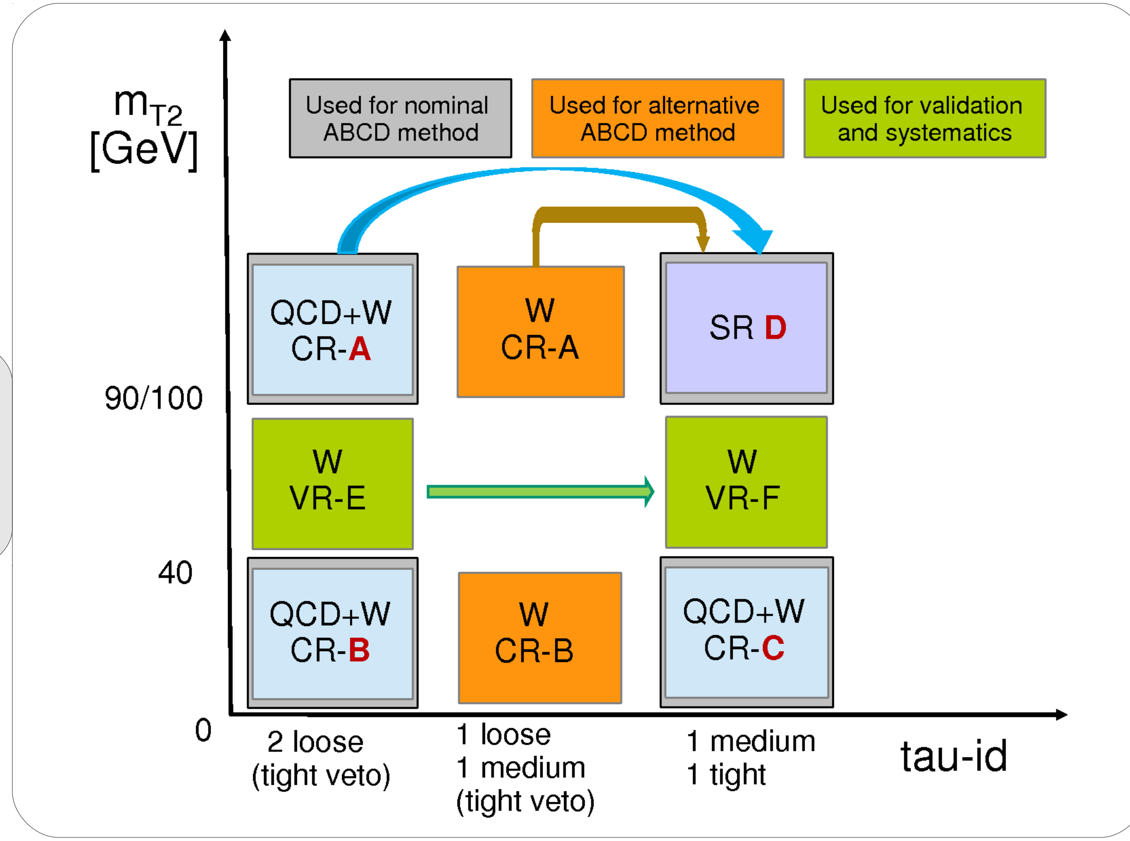
Backup 2τ

2 hadronic τ final states
ATLAS-CONF-2013-028

Standard Model Background Modelling

Irreducible
Z+jets, VV, ttbar, ttbar+V, Wt
MC simulation

Reducible
1 or 2 fake taus
Data-driven ABCD method



SR definitions

Signal region	requirements
OS m_{T2}	at least 1 OS tau pair jet veto Z-veto $E_T^{miss} > 40$ GeV $m_{T2} > 90$ GeV
OS m_{T2}-nobjet	at least 1 OS tau pair b-jet veto Z-veto $E_T^{miss} > 40$ GeV $m_{T2} > 100$ GeV

Systematics

Syst. Sources	SR OS-m_{T2}	SR OS-m_{T2}-nobjet
Correlation	5%	1%
Transfer factor difference	15%	24%
Subtraction of other backgrounds	2%	6%
Number of events in Region A	31%	27%
Total	35%	37%

Results

SM process	SR OS m_{T2}	SR OS m_{T2} -nobjet
top	0.2 ± 0.5 ± 0.1	1.6 ± 0.8 ± 1.2
Z+jets	0.28 ± 0.26 ± 0.23	0.4 ± 0.3 ± 0.3
diboson	2.2 ± 0.5 ± 0.5	2.5 ± 0.5 ± 0.9
multi-jet & W+jets	8.4 ± 2.6 ± 1.4	12 ± 3 ± 3
SM total	11.0 ± 2.7 ± 1.5	17 ± 4 ± 3
data	6	14
SUSY Ref. point 1	6.8 ± 1.0	9.2 ± 1.2
SUSY Ref. point 2	7.5 ± 0.7	8.9 ± 0.7

3 lepton final states (e,μ)
ATLAS-CONF-2013-035

Standard Model Background Modelling

Irreducible
WZ, ZZ, ttbar+V, VVV
MC simulation

Reducible
1 or 2 fake leptons
Data-driven "matrix method"

SR definitions

Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
m_{SFOS} [GeV]	<60	60–81.2	<81.2 or >101.2	81.2–101.2	81.2–101.2	81.2–101.2
$E_{\mathrm{T}}^{\mathrm{miss}}$ [GeV]	>50	>75	>75	75–120	75–120	>120
m_{T} [GeV]	–	–	>110	<110	>110	>110
p_{T} 3rd ℓ [GeV]	>10	>10	>30	>10	>10	>10
SR veto	SRnoZc	SRnoZc	–	–	–	–

Results

Selection	SRnoZa	SRnoZb	SRnoZc	SRZa	SRZb	SRZc
Tri-boson	1.7 ± 1.7	0.6 ± 0.6	0.8 ± 0.8	0.5 ± 0.5	0.4 ± 0.4	0.29 ± 0.29
ZZ	14 ± 8	1.8 ± 1.0	0.25 ± 0.17	8.9 ± 1.8	1.0 ± 0.4	0.39 ± 0.28
$t\bar{t}V$	0.23 ± 0.23	0.21 ± 0.19	$0.21^{+0.30}_{-0.21}$	0.4 ± 0.4	0.22 ± 0.21	0.10 ± 0.10
WZ	50 ± 9	20 ± 4	2.1 ± 1.6	235 ± 35	19 ± 5	5.0 ± 1.4
Σ SM irreducible	65 ± 12	22 ± 4	3.4 ± 1.8	245 ± 35	20 ± 5	5.8 ± 1.4
SM reducible	31 ± 14	7 ± 5	1.0 ± 0.4	4^{+5}_{-4}	1.7 ± 0.7	0.5 ± 0.4
Σ SM	$\mathbf{96 \pm 19}$	$\mathbf{29 \pm 6}$	$\mathbf{4.4 \pm 1.8}$	$\mathbf{249 \pm 35}$	$\mathbf{22 \pm 5}$	$\mathbf{6.3 \pm 1.5}$
Data	**101**	**32**	**5**	**273**	**23**	**6**
p_0-value	0.41	0.37	0.40	0.23	0.44	0.5
N_{signal} excluded (exp)	39.3	16.3	6.2	67.9	13.2	6.7
N_{signal} excluded (obs)	41.8	18.0	6.8	83.7	13.9	6.5
$\sigma_{\mathrm{visible}}$ excluded (exp) [fb]	1.90	0.79	0.30	3.28	0.64	0.32
$\sigma_{\mathrm{visible}}$ excluded (obs) [fb]	2.02	0.87	0.33	4.04	0.67	0.31

4 lepton final states (e,μ,τ)
ATLAS-CONF-2013-036

Standard Model Background Modelling

Irreducible
ZZ, ttbar+V, VVV, Higgs
MC simulation

Reducible
1 or 2 fake leptons
Data-driven "weighting method"

SR definitions

SR	$N(\ell = e,\mu)$	$N(\tau)$	Z Candidate	E_T^{miss}[GeV]		m_{eff}[GeV]	Scenario
SR0noZa	≥4	≥0	extended veto	>50			RPC
SR0noZb	≥4	≥0	extended veto	>75	or	>600	RPV
SR1noZ	=3	≥1	extended veto	>100	or	>400	RPV
SR0Z	≥4	≥0	request	>75			GGM
SR1Z	=3	≥1	request	>100			GGM

Results

Sample	SR0noZa	SR0noZb	SR1noZ	SR0Z	SR1Z
ZZ	0.6 ± 0.5	0.50 ± 0.26	0.19 ± 0.05	1.2 ± 0.4	0.49 ± 0.10
ZWW	0.12 ± 0.12	0.08 ± 0.08	0.05 ± 0.05	0.6 ± 0.6	0.13 ± 0.13
$t\bar{t}Z$	0.73 ± 0.34	0.75 ± 0.35	0.16 ± 0.12	2.3 ± 0.9	0.29 ± 0.24
Higgs	0.26 ± 0.07	0.22 ± 0.07	0.23 ± 0.06	0.58 ± 0.15	0.14 ± 0.05
Irreducible Bkg.	1.7 ± 0.8	1.6 ± 0.6	0.62 ± 0.21	4.8 ± 1.8	1.1 ± 0.4
Reducible Bkg.	$0^{+0.16}_{-0}$	$0.05^{+0.14}_{-0.05}$	1.4 ± 1.3	$0^{+0.14}_{-0}$	$0.3^{+1.0}_{-0.3}$
Total Bkg.	1.7 ± 0.8	1.6 ± 0.6	2.0 ± 1.3	4.8 ± 1.8	$1.3^{+1.0}_{-0.5}$
Data	2	1	4	8	3
p_0-value	0.29	0.5	0.15	0.08	0.13
N_{signal} Excluded (exp)	3.9	3.6	5.3	6.7	4.5
N_{signal} Excluded (obs)	4.7	3.7	7.5	10.4	6.5
$\sigma_{visible}$ Excluded (exp) [fb]	0.19	0.17	0.26	0.32	0.22
$\sigma_{visible}$ Excluded (obs) [fb]	0.23	0.18	0.36	0.50	0.31

Backup 4L

4 lepton final states (e,μ,τ)
ATLAS-CONF-2013-036

Validation region definitions

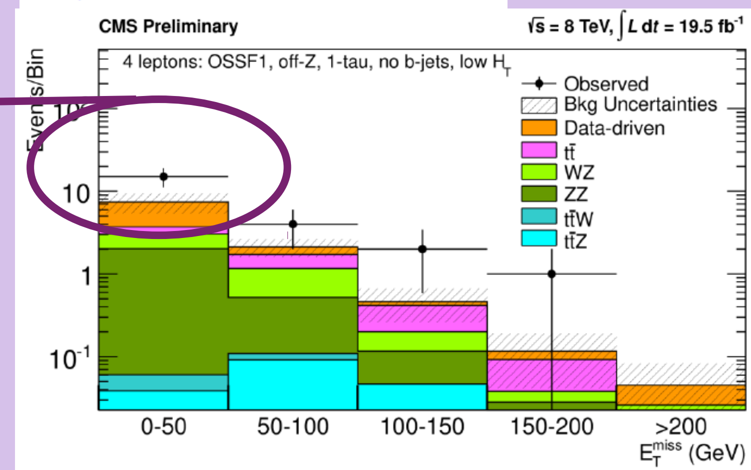
VR	N($\ell = e, \mu$)	N(τ)	Z Candidate	E_T^{miss}[GeV]		m_{eff}[GeV]	Dominant Background
VR0noZ	≥4	≥0	extended veto	<50	and	<400	Z^*Z^*
VR1noZ	=3	≥1	extended veto	<50	and	<400	Z^*Z^*, WZ^*, Z^*+jets
VR0Z	≥4	≥0	request	<50			ZZ
VR1Z	=3	≥1	request	<50			ZZ, WZ, Z+jets

Validation region agreement

Sample	VR0noZ	VR1noZ	VR0Z	VR1Z
ZZ	7.2 ± 3.6	1.45 ± 0.30	167 ± 38	8.0 ± 1.2
ZWW	0.031 ± 0.031	0.027 ± 0.027	0.35 ± 0.35	0.10 ± 0.10
$t\bar{t}Z$	$0^{+0.05}_{-0}$	$0^{+0.10}_{-0}$	1.5 ± 0.7	0.18 ± 0.14
Higgs	0.17 ± 0.05	0.23 ± 0.05	4.5 ± 0.9	0.64 ± 0.16
Irreducible Bkg.	7.4 ± 3.6	1.70 ± 0.34	173 ± 39	8.9 ± 1.4
Reducible Bkg.	$0.3^{+0.7}_{-0.3}$	7.9 ± 3.6	$2.0^{+2.6}_{-2.0}$	28 ± 10
Total Bkg.	7.7 ± 3.4	9.6 ± 3.6	175 ± 37	37 ± 10
Data	3	10	201	31
CL_b	0.10	0.54	0.51	0.30

CMS-SUS-13-002

Categorie:
4 leptons, OSSF1, off-Z,
including 1 τ,
no b-tags, HT< 200 GeV
Observe = 22 events
Expected = 10 ± 2.4 events



Excess in VR1noZ-like region.

Not seen by ATLAS